Office of Energy Efficiency & Renewable Energy

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Real-Time Weather Data Access Guide

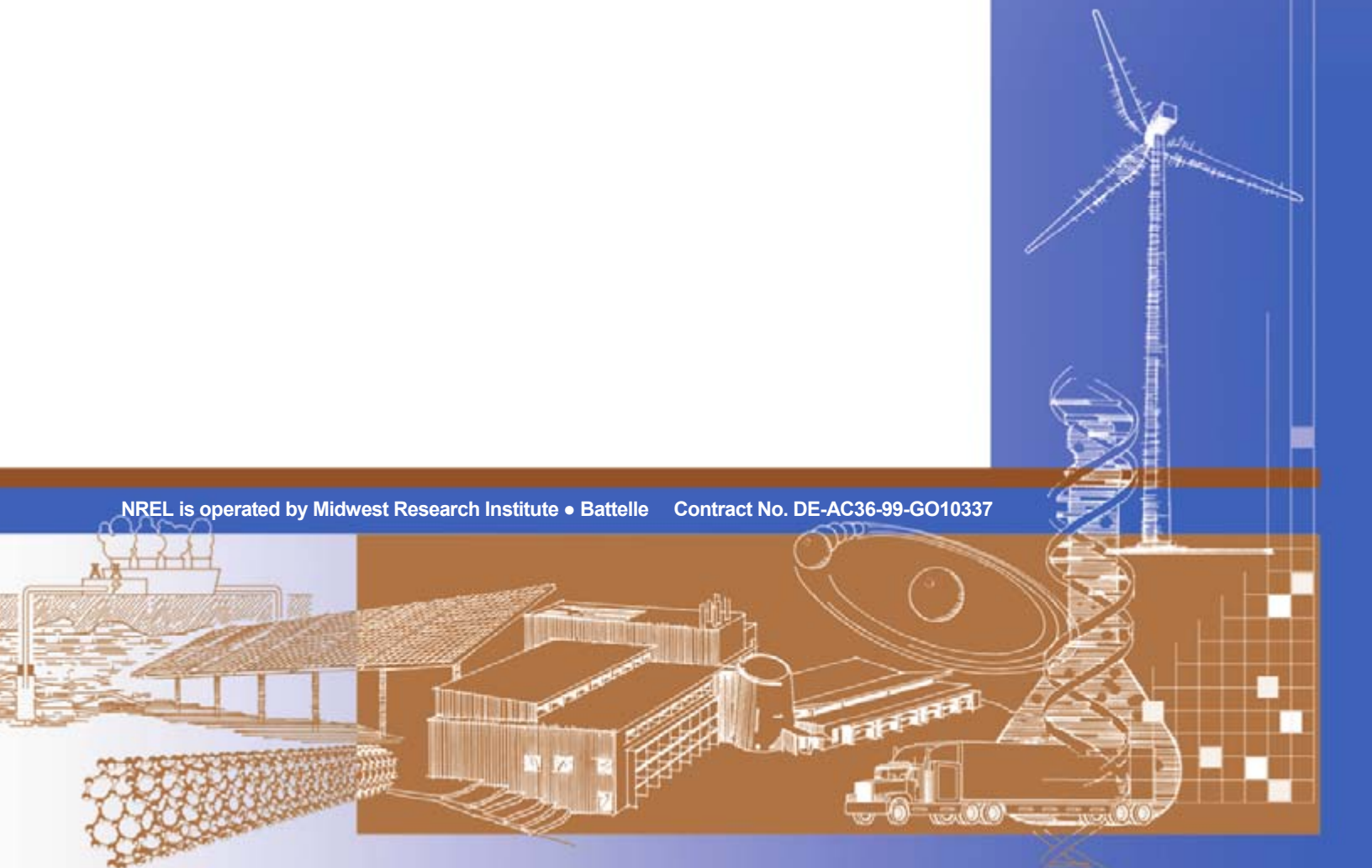
Updated February 2006

N. Long

User's Guide

NREL/BR-550-34303

March 2006



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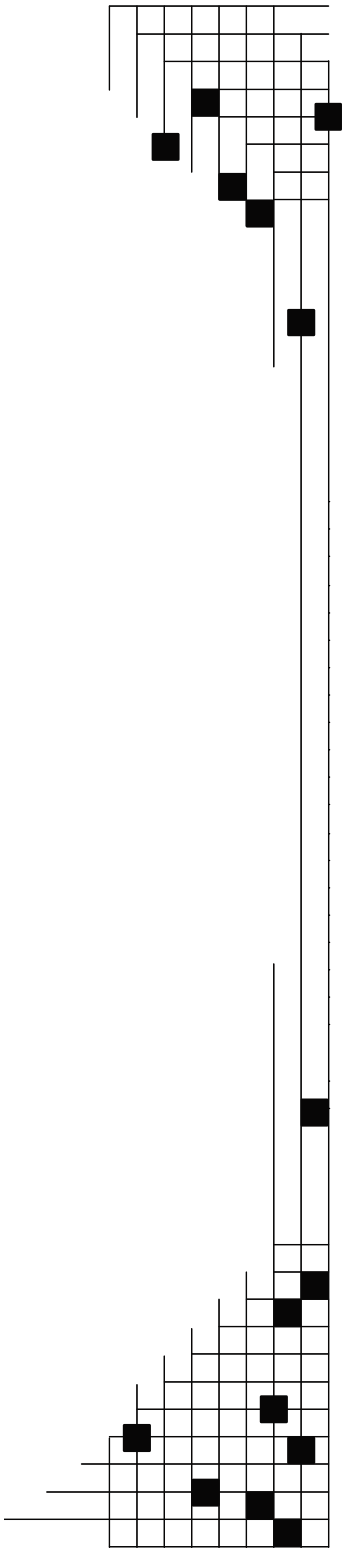

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401-3393
303-275-3000 • www.nrel.gov

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Introduction

The National Weather Service (NWS) collects weather information from stations around the world. There are approximately 4,000 stations in the world that are currently monitored. This weather information is collected, parsed, and stored into a local database at the National Renewable Energy Laboratory (NREL). The data are available to anyone via the Internet and e-mail.

This database is based on an earlier database developed by the Gas Technology Institute (GTI, formerly the Gas Research Institute) beginning in 1998 for 234 locations in the United States. GTI and its subcontractors (Mason-Grant and Rocket Science) graciously donated that data and allowed DOE to incorporate it into this new database—providing data for some locations from late 1998 through today (although there may be significant gaps in the data).

The accuracy and continuity of the data is dependent on many procedures operating seamlessly. The NWS ftp site must be active, the local data collection computer must be on and stable, and local Internet services must be available. If any of these variables are unavailable then missing data will occur. Also, the data received is only as good as the data reported. The parser and database does not determine if the data was off by a certain percent because of a failing sensor or unusual conditions during the time of the reading. The majority of the data that is collected is the dry bulb/dew point temperatures, pressure, and wind conditions. In some cases more information was available and is included in the database. This paper will document how the data are parsed, how the data are filled, and how to access the database.

Parsing Data

The weather-parsing program allows for gigabytes of data to be processed into an accessible indexed database format. The current format of the weather data received by the NWS is extremely inconvenient to read especially for trending historical data; therefore, a parsing program was created to simplify the data. Even though there are many consistent errors with the format of the weather data files, the data parser checks for many of the errors and compensates for them.

Many stations have multiple readings around the hour. The program finds the closest entry to the hour and uses those values. However, if newer information (such as cloud cover) is received in a reading and that data point is not already stored, then the new data point is stored as if it occurred for that hour. The overwriting of old data will not occur unless the new time stamp is closer to the hour of interest or the value was not previously stored.

Filling Data

The weather database does not have a contiguous collection of data. There are basically two different failure areas; the first is on the NREL side where the connection to the Internet was interrupted either by a network failure or a computer failure preventing the weather data to be downloaded. The other failure area is on the NWS side, where the station was not accessed to collect the data and store it in a file. Also, heavy traffic to the NWS ftp site has prevented several data sets from being retrieved.

Upon request of the data, the missing data can be exported with interpolated values for the holes. The filled values are not stored in the database; they are calculated every time a data request is received. If the user requests filled data there are two different routines that operate to smooth the data while a third routine simply breaks the file and skips the missing data. The only data that are

filled are the dew point and dry bulb temperatures. If the missing period is less then 6 hours then the data are simply filled linearly or as seen in Equation (1).

$$f(t_n) = f(t_1) + \left(\frac{f(t_2) - f(t_1)}{t_2 - t_1} \right) \cdot n \tag{1}$$

Where: $f(t_n)$ is the time step to fill

$f(t_1)$ and $f(t_2)$ are the values around the missing time step

If there are more than 6 hours and less then 48 hours of missing data, then the data are filled by taking the trend of the first previous day that is valid as seen in Equation (2). The trend is offset by the values that surround the missing data to smooth the filled data.

$$f(t_n) = f(t_{n-d}) + \left(f(t_1) - f(t_{1-d})\right) + \left(\frac{\left(f(t_2) - f(t_{2-d})\right) - \left(f(t_1) - f(t_{1-d})\right)}{t_2 - t_1 + 1} \right) \cdot n \tag{2}$$

Where: $f(t_n)$ is the time step to fill

$f(t_1)$ and $f(t_2)$ are the values around the missing time step

d is the offset back to the previous valid day

If the missing data covers more than 48 hours, then the program creates a new file where the data starts again. The naming convention for the new filename is an underscore and the valid file dates, for example: KDEN_20020824-20031015.

The filling data routine does not scan for values outside of a given range, for instance if the temperature suddenly dropped 50ºC, then there must have been an error with the reading of the station or parsing of the data file. In this case the user must manually identify these outliers and correct them.

Note: When filling, if the dew point temperature is larger than the dry bulb then the program will force the dew point to equal the dry bulb.

Verification of Filling Routines

Figure 1 shows the dew point and dry bulb temperatures for the real data and filled data. This is the worst-case scenario because an abundant amount of data is missing over several days. For the large pieces of missing data, the trend is continued from the previous days, while for the smaller pieces of missing data the trend is linear.

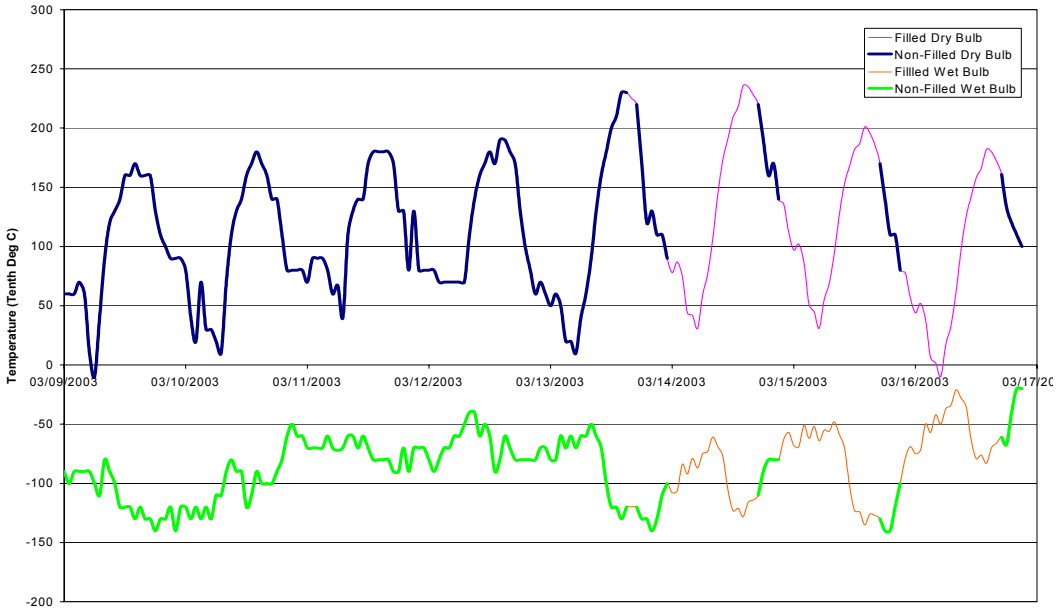

Figure 1. Filling routine verification

Accessing the Database

Requesting Data

There are two different methods to retrieve data from the database. The preferred way to request data is to access the weather request web page currently located at http://www.eere.energy.gov/buildings/energyplus/cfm/weatherdata/weather_request.cfm. The process is simple and outlined on the web page. It is possible to enter the 4-character ICAO station ID directly or to search for a valid ID by selecting the "search" option on the home page. Upon completion of the request, data should be sent within an hour.

The second way of retrieving data is to manually send an email to weather@nrel.gov with a specific format. It is suggested to use the web interface explained in the previous paragraph because a mistype in the e-mail may prevent the data from being sent. However, if it is chosen to use a manual e-mail, the format must be as follows:

Table 1 Format for Manual E-mail

Format	Example
To: weather@nrel.gov Subject: Weather Data Body: StationID=<Enter 4-character ICAO Station ID> StartDate=<Enter Start Date in MM/DD/YYYY> EndDate=<Enter End Date in MM/DD/YYYY> OutputType=<1 for CSV, 2 for IWEC> FillData=<0 for No, 1 for Yes>	To: weather@nrel.gov Subject: Weather Data Body: StationID=KDEN StartDate=08/24/2002 EndDate=10/15/2002 OutputType=1 FillData=1

The station ID must be on the first line of the body and appear exactly as above. Also, it is not necessary to enter the greater than or less than signs in the text. The format of the start date and end date are the same. If the dates entered in the StartDate and EndDate fields are out of range of the actual data, then the program will converge on the valid dates. If the e-mail is in the correct format and the return address is valid, then the user should receive an e-mail with the data within an hour.

If no data are received within eight hours, the process should be repeated. Certain e-mail clients do not allow for large attachments to be sent during peak hours. In this case the data may take longer to receive. Also, some e-mail clients do not allow for large attachments at all. In this case the requester should break up the dates to receive smaller files, then piece the files together manually.

It is possible that no information is to be found for the station entered and in this case an empty email will be returned to the user. If the data request occurs during the night or during a weekend (MDT) then the process may take longer because maintenance operations are running during these hours.

Station Listings

It is possible to retrieve a listing of all the valid stations and the data range by selecting "Retrieve a list of stations and data availability" on the web page or by sending an e-mail to weather@nrel.gov with "Station Listings" in the subject (the body can be blank).

The format of the station file is below. It is semicolon delimited with the following information in each column, starting at column 1. If the entry is null, then the column will contain a period.

Table 2 Station File Format

Column	Units/Notes
1. Irrelevant	
2. Irrelevant	
3. Station ID	ICAO Code
4. Station Name or Airport Name	
5. City	
6. State or Providence	If Available
7. Country	
8. Continent Index	
9. Latitude	Degrees, Minutes
10. Longitude	Degrees, Minutes
11. Elevation in Meters	Meters
12. WMO Identifier – IWEC Code	
13. Time Zone Offset From GMT	
14. First Valid Timestamp	
15. Last Valid Timestamp	
16. Number of Valid Records	
17. Percentage of Valid Records	
18. Latitude in Radians	
19. Longitude in Radians	
20. County	
21. Alternate 3-character Station Code	

This file is automatically created every weekend to update the valid station dates. Also, the database is continually adjusted to reflect station information because exhaustive information (such as GMT to LST offsets) for the stations could not be found and are continually adjusted when new information is found.

Weather Output Format

After a request has been received via the e-mail with appropriate fields, the local program will attempt to output the data. If there was an error with the e-mail format (this will typically occur if the user manually sends an email instead of using the web interface) then the user will receive an email with the correct format outlined in the body. If no data are available for the site, then the user will receive an email with an attachment stating "Station or Data For Station Not Found." Other errors may occur if the subject has the wrong title. If no email is received within 8 hours, try requesting the data again.

When requesting data, the program searches for a station listing that details the parameters of the station such as longitude, latitude, and time offset for Greenwich Mean Time (GMT). All data requests are in GMT. If the user requests data that is outside of the available time stored in the database, then the program will only report the data that falls within the bounds. If no station information was found or the time offset was not present, then a line in the output file will warn the user that the time stamps are not in local standard time. All IWEC files need to be in local standard time before using them in an energy simulator. Conversely, if the time offset values are found, then the time stamps will be in local standard time.

The output of the weather data is available in two formats: Comma Separated Values (CSV) and International Weather for Energy Calculations (IWEC).

CSV

The CSV files have the following columns and respective units:

Table 3. Column and Units of CSV Files

Column	Units/Notes
1. Local Date and Time	MM/DD/YYYY HH:MM[1]
2. Greenwich Mean Time[1]	MM/DD/YYYY HH:MM
3. Dry Bulb Temperature	Tenths of Degree Celsius
4. Dew Point Temperature	Tenths of Degree Celsius
5. Wind Direction	Degrees (0º = North)
6. Wind Speed	Tenths of Meter Per Second
7. Wind Gusts	Tenths of Meter Per Second
8. Wind Variability	Range in Degrees
9. Altimeter	Hundreds of Pascals
10. Visibility	Tenths of Kilometers
11. Weather Description	MI, BC, PR, TS, BL, SH, DR, F
12. Weather Precipitation	DZ, RA, SN, SG, IC, PL, GR, GS, UP
13. Weather Observation	BR, FG, FU, VA, SA, HZ, PY, DU
14. Weather Other	SQ, SS, DS, PO, FC
15. Cloud Cover Level 1	Identifier + Height in Hundreds of Feet
16. Cloud Cover Level 2	Identifier + Height in Hundreds of Feet
17. Cloud Cover Level 3	Identifier + Height in Hundreds of Feet
18. Sea Level Pressure	Hundreds of Pascals

More information on the cloud cover and weather descriptors can be found in the *Surface Weather Observations and Reports Handbook,* http://www.ofcm.gov/fmh-1/pdf/fmh1.pdf. [1]. If filled data is requested then there will be an asterisk next to the filled value. An easy way to remove the asterisk is to load the data into Microsoft Excel and type the following formula into the cell adjacent to the asterisk. The "XX" is the cell that contains the data. Simply fill this formula, (3), down to the end of the column.

$$= IF(Right(Trim(XX),1) = "*", Value(Left(Trim(XX), Len(Trim(XX)) - 1)), XX) \quad (3)$$

IWEC

The IWEC format is based on the field position. The information in the IWEC file is available in the IWEC manual published by ASHRAE. [2].

Contact

For more information please contact Nicholas Long, nicholas_long@nrel.gov. Do not e-mail questions to weather@nrel.gov because a person does not read these e-mails.

[1] If the program does not find a valid GMT offset for the station, then this column will be the same as GMT.

FAQ

Q. How can I get help?

A. First, download the manual, http://www.eere.energy.gov/buildings/energyplus/pdfs/weatherdata_guide_34303.pdf. After reading the manual, if you still have questions you can e-mail Nicholas Long, nicholas_long@nrel.gov. Do not use weather@nrel.gov because a person does not read the e-mails.

Q. Why are there multiple files in the e-mail?

A. Since there are many variables needed to make this process operate seamlessly, missing data may occur from time to time. If there are more than 48 consecutive hours of missing data, then the data file is closed and a new file is created where the data starts again.

Q. What are the available formats for output?

A. There are two formats available for output: Comma Separate Values (CSV) and International Weather for Energy Calculations (IWEC). CSV is the raw data separated by commas for easy import into several different spreadsheet programs. IWEC files contain a specific format used by programs to evaluate energy performance of buildings. For more information on IWEC files visit http://www.eere.energy.gov/buildings/energyplus/weatherdata_sources.html.

Q. What are the units when the data are in CSV format?

A. The columns and units in the CSV format are as follows:

Table 4. Column and Units of CSV Files

Column	Units/Notes
1. Local Date and Time	MM/DD/YYYY HH:MM[1]
2. Greenwich Mean Time	MM/DD/YYYY HH:MM
3. Dry Bulb Temperature	Tenths of Degree Celsius
4. Dew Point Temperature	Tenths of Degree Celsius
5. Wind Direction	Degrees (0º = North)
6. Wind Speed	Tenths of Meter Per Second
7. Wind Gusts	Tenths of Meter Per Second
8. Wind Variability	Range in Degrees
9. Altimeter	Hundreds of Pascals
10. Visibility	Tenths of Kilometers
11. Weather Description	MI, BC, PR, TS, BL, SH, DR, F
12. Weather Precipitation	DZ, RA, SN, SG, IC, PL, GR, GS, UP
13. Weather Observation	BR, FG, FU, VA, SA, HZ, PY, DU
14. Weather Other	SQ, SS, DS, PO, FC
15. Cloud Cover Level 1	Identifier + Height in Hundreds of Feet
16. Cloud Cover Level 2	Identifier + Height in Hundreds of Feet
17. Cloud Cover Level 3	Identifier + Height in Hundreds of Feet
18. Sea Level Pressure	Hundreds of Pascals

[1]If the program does not find a valid GMT offset for the station then this column will be the same as GMT.

Q. What are the units when the data are in IWEC format?

A. The format for the IWEC files are very cryptic, to get a full understanding of IWEC files download the IWEC Manual published by ASHRAE. The units of the data are as follows:

Table 5. Column and Units of IWEC Files

Entry	Units/Notes
Local Date and Time	YYYYMMDDHH
Dry Bulb Temperature	Tenths of Degree Celsius
Dew Point Temperature	Tenths of Degree Celsius
Wind Direction	Degrees (0º = North)
Wind Speed	Tenths of Meter Per Second
Altimeter	Hundreds of Pascals
Visibility	Tenths of Kilometers

If the program does not find a valid GMT offset for the station, then the data will state that an error occurred while trying to offset the data. In this instance, all the data is in GMT and should be converted by the user. Also, the hours are from 1 to 24 not 0 to 23.

Q. What time zone is the data reported in?

A. All the data are stored in Greenwich Mean Time (GMT) but upon retrieval, the program attempts to convert the time steps to local standard time (LST). If the time steps are not converted, it is most likely because the station database did not contain an offset variable for the time zone. Also, when the time steps are not converted, a warning line is inserted into the data file to warn that the steps are incorrect and that they need to be corrected manually.

Q. How are missing data filled?

A. When there are missing data, the requestor has the option of filling the hole or leaving it blank. If the user requests filled data there are two different routines that operate to smooth the data while a third routine simply breaks the file and leaves the missing data empty. The only data that are filled is the dew point and dry bulb temperatures. If the missing period is less then 6 hours, then the data are simply filled linearly. If there are more than 6 hours and less then 48 hours of missing data, then the data are filled by taking the trend of the first valid previous day. The trend is offset by the values that surround the missing data to smooth the filled data.

If the missing data covers more than 2 days or 48 hours, then the program creates a new file where the data starts again. The naming convention for the new filename is an underscore and the valid file dates, for example KDEN_20020824-20031015.

Note: When filling data, if the dew point temperature is larger than the dry bulb then the program will force the dew point to equal the dry bulb.

Q. Does the parser check the data to make sure the values seem reasonable?

A. No, the parser does not check the data for reasonability. There are cases when the temperature increases or decreases more than a reasonable amount. Manual plotting or subsequent processing on the data sets should be used to determine these values.

Q. Can I receive data without having the data filled?

A. Yes, when you request the data from the web page make sure the “Fill Missing Time Steps” under “Step 2: Choose Dates and Formats” checkbox is *not* selected. The data you receive will only contain the data that is stored in the local database.

Q. What is the asterisk and can I remove it for the data in CSV Format?

A. The asterisk indicates that the data point was filled. The best way to remove the asterisks for the filled data is to import all the data into Microsoft Excel, make sure to put the data into individual columns by selecting "Text to columns" under the "Data" menu. Create new columns next to the columns of data that contain the asterisks. In the new columns enter the following formula:

$$=IF(Right(Trim(XX,1)="*",Value(Left(Trim(XX),Len(Trim(XX))-1)),XX) \quad (4)$$

Where XX is the cell that contains the first data point with or without the asterisk. Then simply fill this formula down to the end of the column.

Q. What is the file naming convention?

A. The typical naming convention is the station ID with the start date and end date appended. For example KDEN_20020824-20021015.csv contains data for Denver from August 24, 2002 through October 15, 2002. If you chose to have IWEC information, then if the WMO code is found in the station database, then the station ID is replaced with the WMO code. For example 724760_20020824-20021015.iwc contains the same information as above but in IWEC format.

Q. Why are the dates in the file different than the dates I requested?

A. If you requested data that were not available in the database, then the dates are automatically adjusted to include any dates that fall within the requested range.

Q. How do I interpret the Stations Listing File?

A. The station file is comma delimited and contains the following information in each column:

Table 6. Station File Format

Column	Units/Notes
1. Irrelevant	
2. Irrelevant	
3. Station ID	ICAO Code
4. Station Name or Airport Name	
5. City	
6. State or Providence	If Available
7. Country	
8. Continent Index	
9. Latitude	Degrees, Minutes
10. Longitude	Degrees, Minutes
11. Elevation in Meters	Meters
12. WMO Identifier – IWEC Code	
13. Time Zone Offset From GMT	
14. First Valid Timestamp	
15. Last Valid Timestamp	
16. Number of Valid Records	
17. Percentage of Valid Records	
18. Latitude in Radians	
19. Longitude in Radians	
20. County	

Q. What is the source of the data?

A. The National Weather Service (NWS) collects weather information from stations across the world in METAR format. There are over 4,000 stations in the world that are currently monitored. This weather information is collected, parsed, and stored into a local database at the National Renewable Energy Laboratory (NREL).

Q. What happens if my mail server does not allow large attachments?

A. Certain e-mail clients do not allow for large attachments to be sent during peak hours. In this case the data may take longer to receive. Also, some e-mail clients do not allow for large attachments at all. In this case the requester should break up the dates to receive smaller files, then piece the files together manually. If you believe your mail client does not allow large attachments, then please wait 24 hours before requesting the data again.

References

[1] *Surface Weather Observations and Reports*. FCM-H1-1995. Washington, D.C.: U.S. Department of Commerce/National Oceanic and Atmospheric Administration. December 1995.

[2] *International Weather for Energy Calculations (IWEC Weather Files) User's Manual.* ASHRAE. March 31, 2001.